Characterization of advanced EUV resists using the Berkeley MET tool

Patrick Naulleau

Lawrence Berkeley National Laboratory

Special Thanks

Chris Anderson

University of California, Berkeley

Ryoung-han Kim, Bruno La Fontaine, Tom Wallow

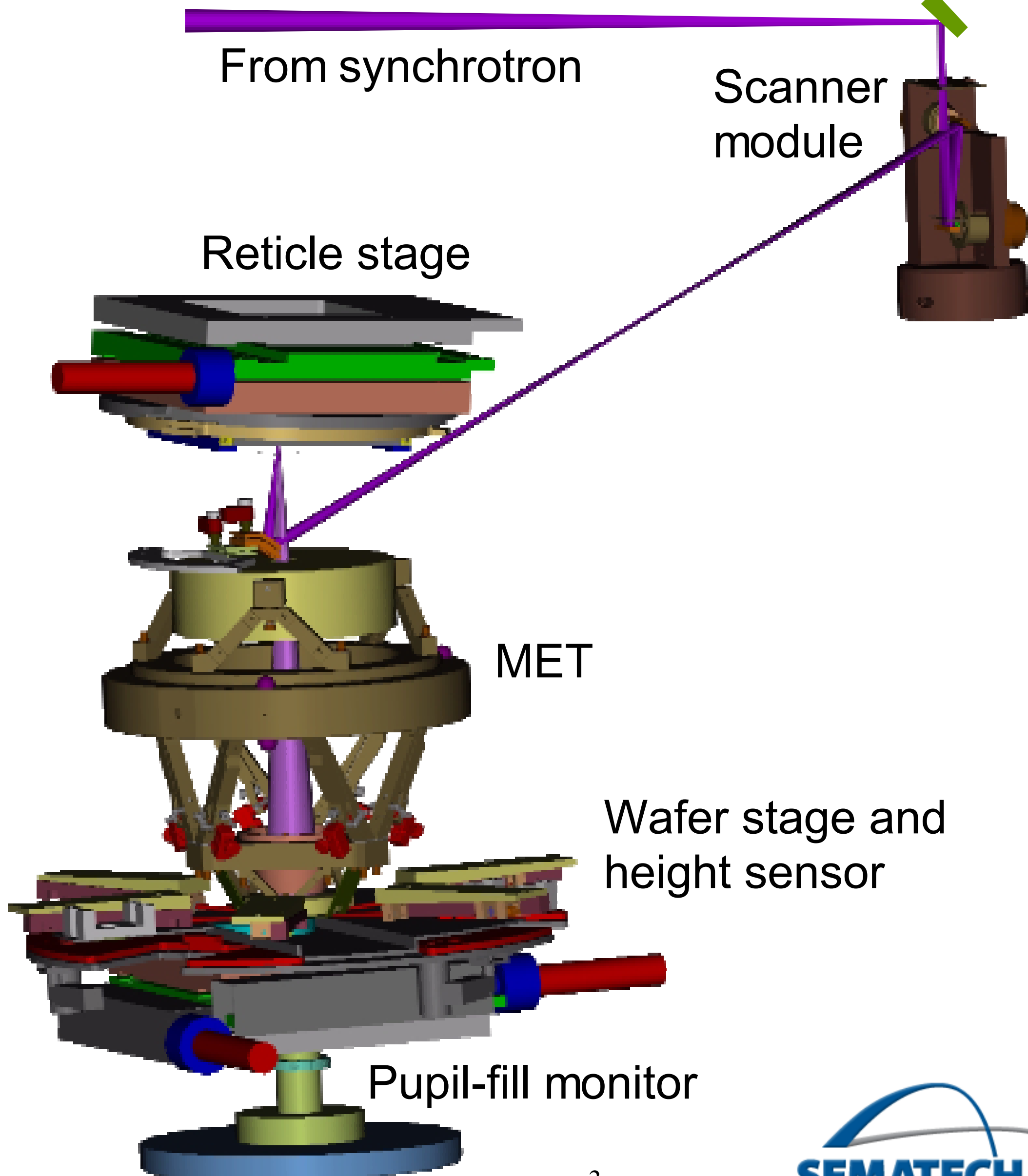
AMD

Outline

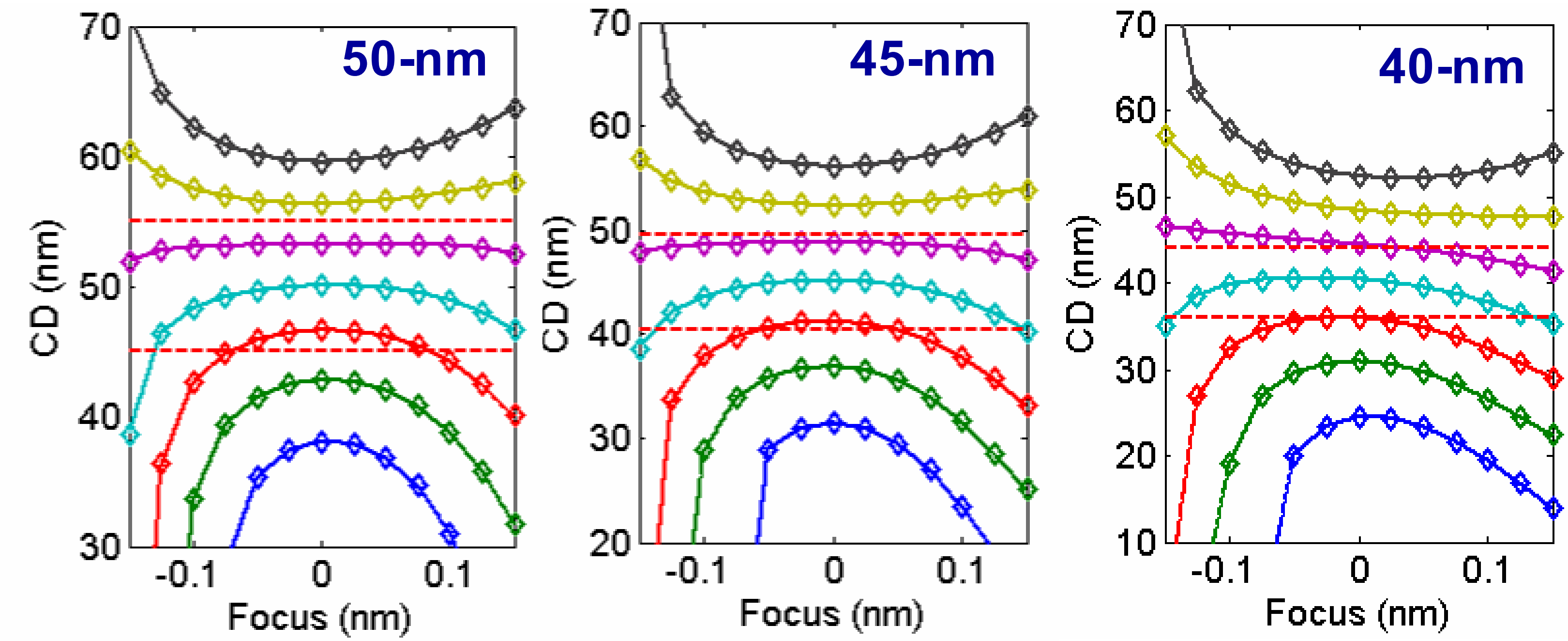
- Capabilities of the Berkeley MET tool
- Demonstration of resist-limited performance
- Constraints on resist development
- Metrics for intrinsic resolution
- Champion resist results from the Berkeley MET tool
- Summary

Berkeley MET exposure tool

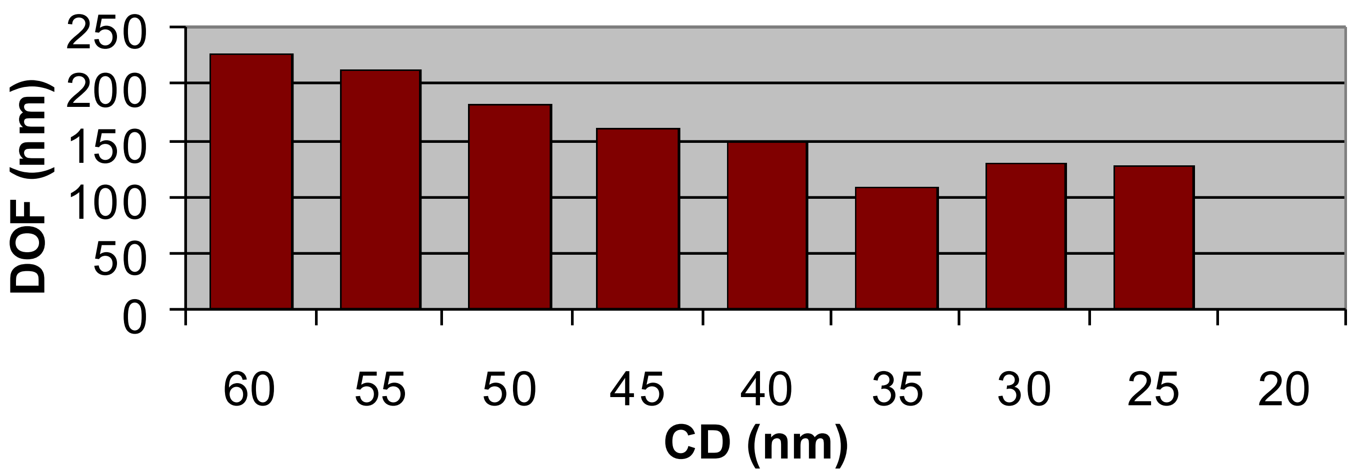
- Based on MET optic
- Magnification = 5x, NA = 0.3
- Rayleigh resolution = 27 nm
- Field size = 200x600 μm
- Programmable coherence illuminator for low k_1
- Reticle and wafer load-lock systems
- nm-resolution wafer-height sensor and focus actuation
- Pupil-fill monitor



Berkeley MET modeled to have good DOF down to 25 nm with annular illumination

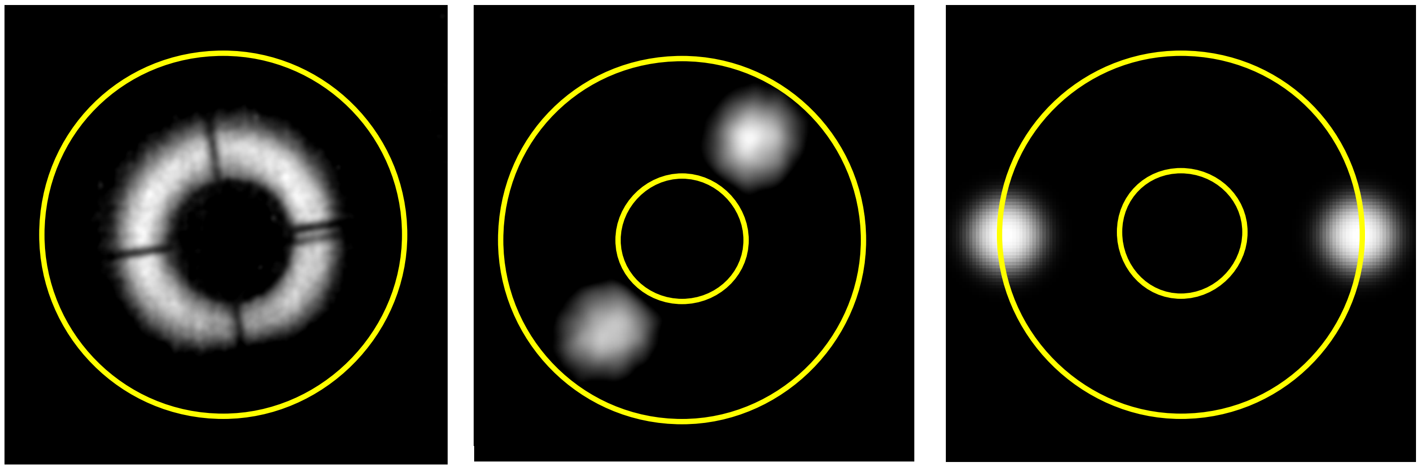


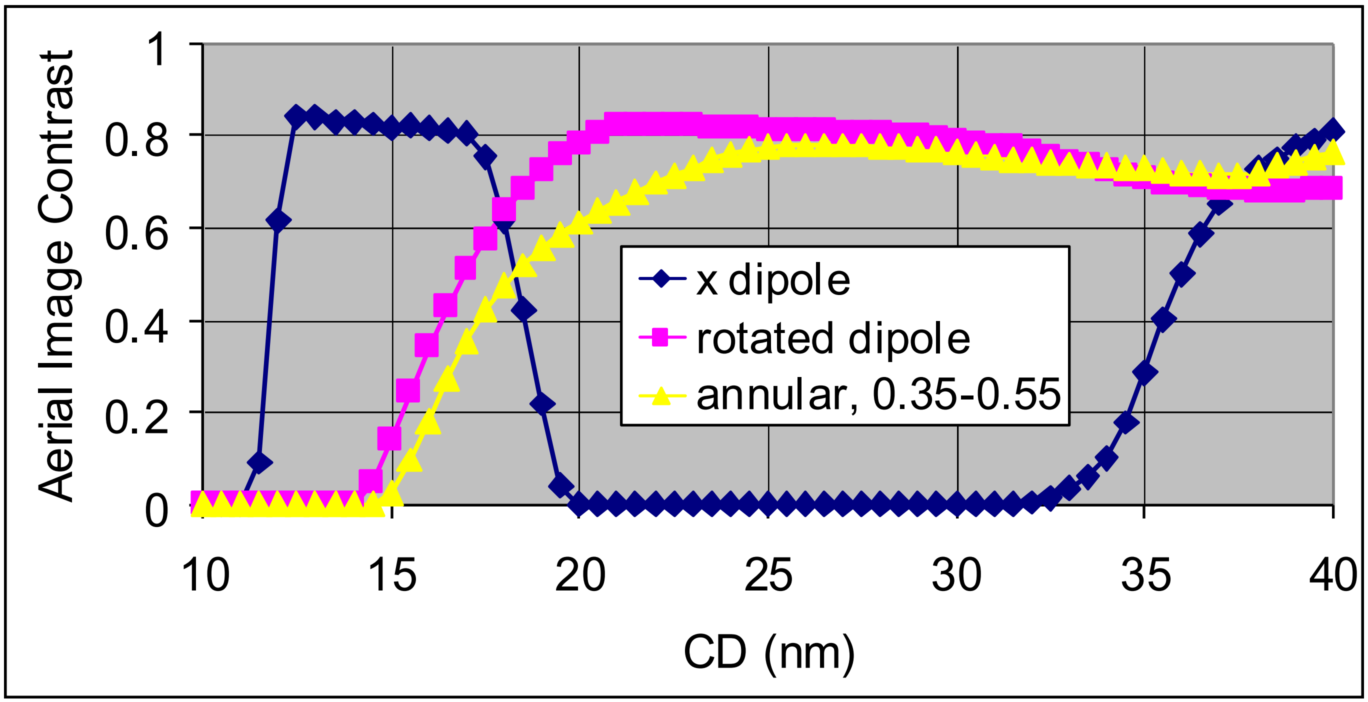
Bossungs based on 10% dose increments



Predicted aerial-image DOF:
+/-10% CD control
10% Total EL
contrast > 45%
ILS > 20

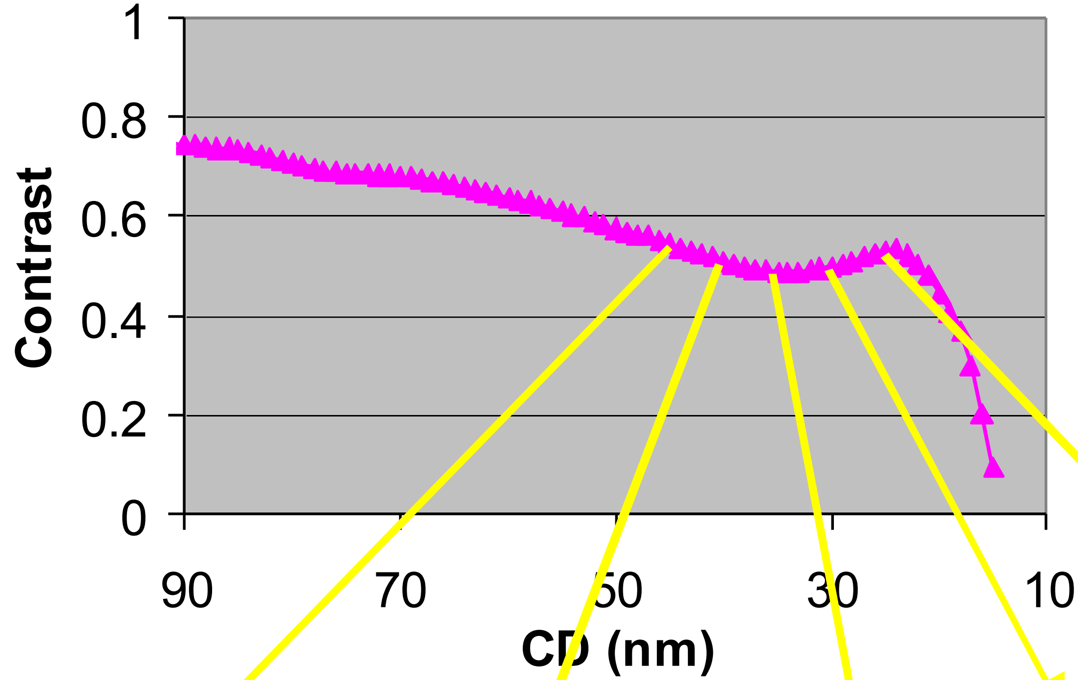
Programmable coherence capabilities enable ultra-high resolution printing



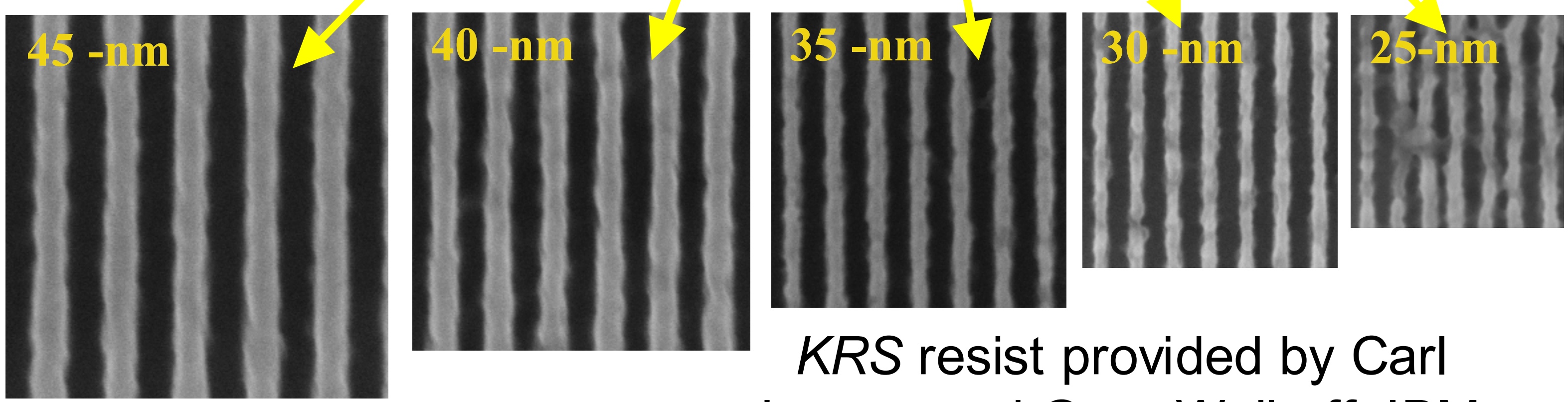


- *Prolith* modeling results including EUV-measured wavefront.

Even with best EUV resists, resolution limit determined by resist not aerial image



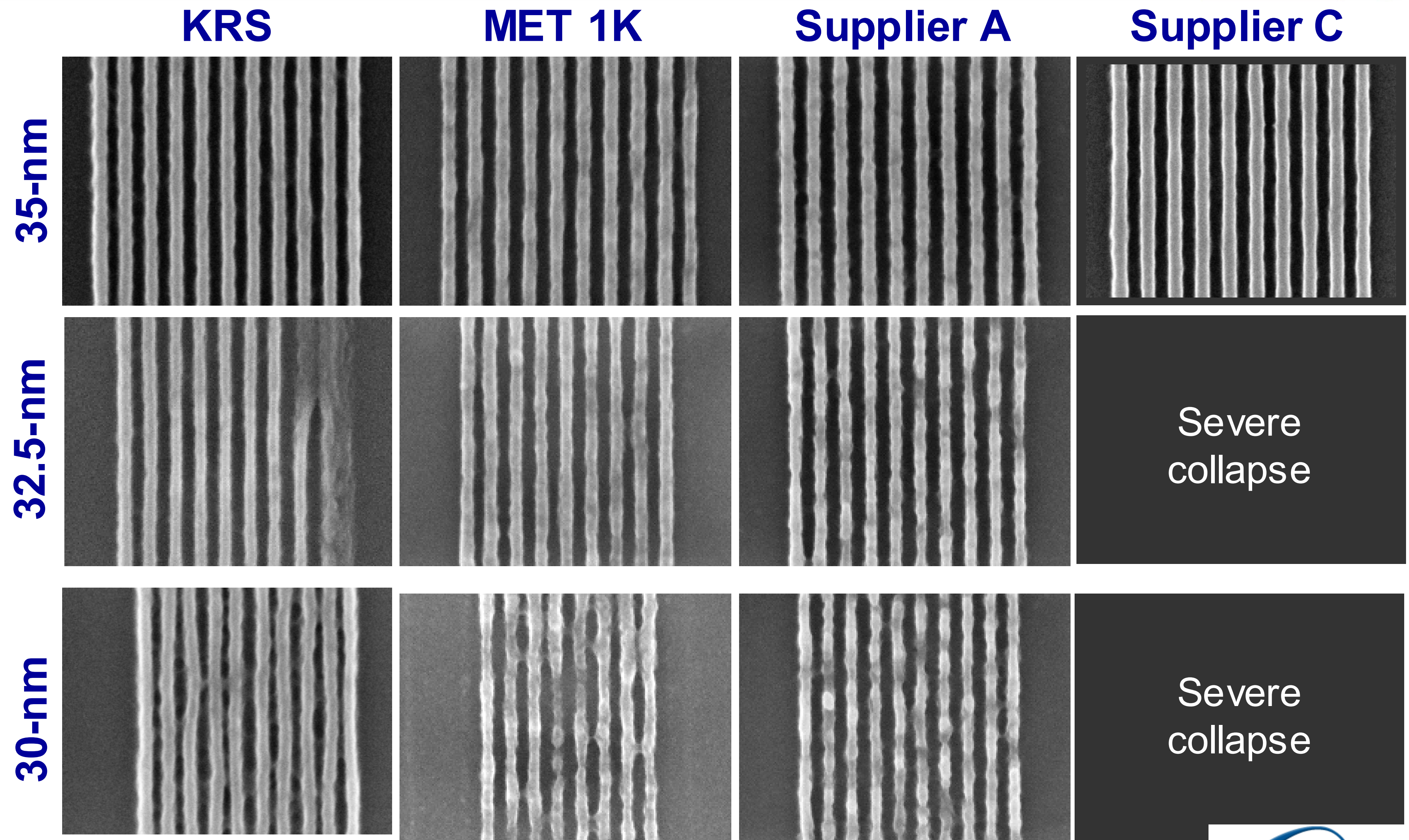
Predicted aerial-image contrast



KRS resist provided by Carl Larson and Greg Wallraff, IBM

LBNL-MET, annular

Status in late 2005 showed a resolution limit in EUV CAR of ~32 nm

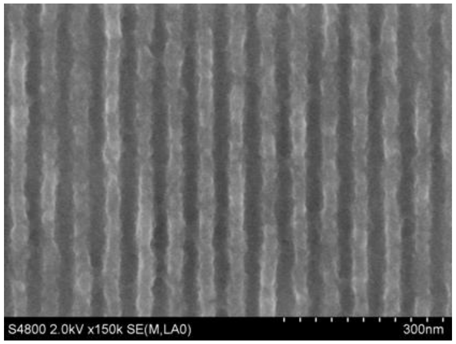


LBNL-MET, Y-Monopole

Dose limitations places severe restrictions on levers available for improved resolution

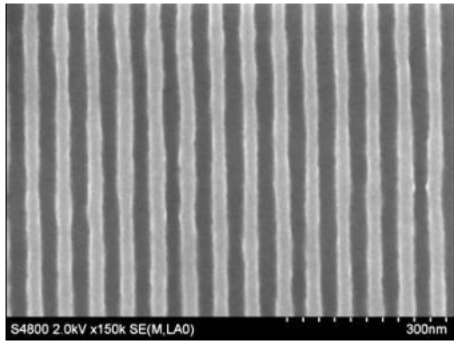
MET 1K	XP6627-Q	XP6627-G	XP6627-T

MET 1K



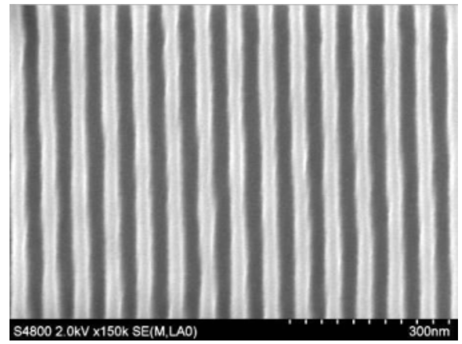
32nm hp, 22.7mJ/cm2

XP6627-Q



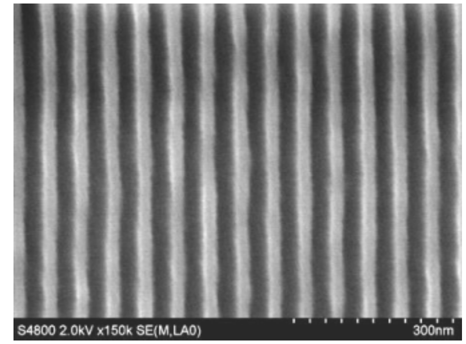
32nm hp, 46.3mJ/cm2

XP6627-G

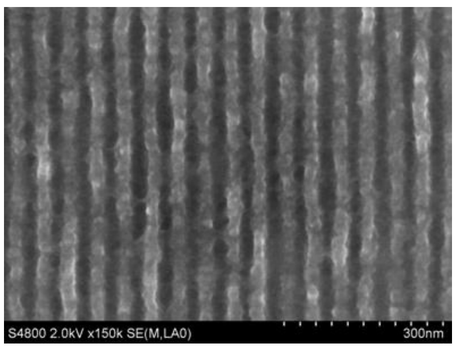


32nm hp, 71.6mJ/cm2

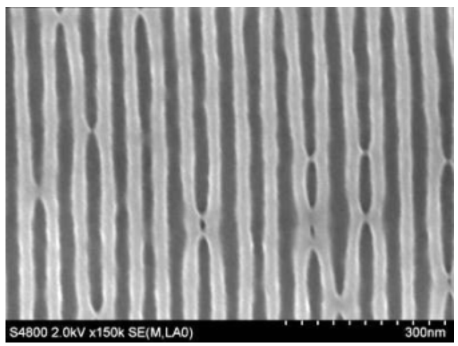
XP6627-T



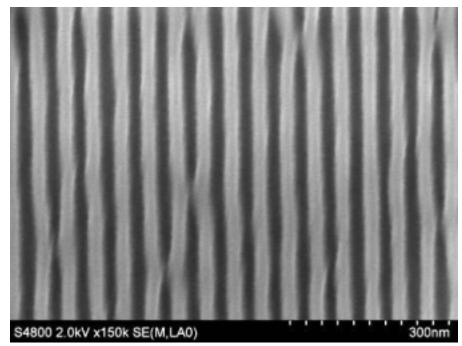
32nm hp, 79.1mJ/cm2



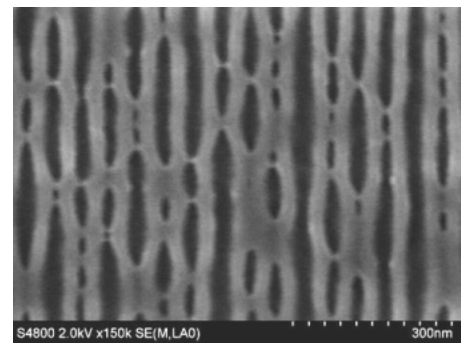
28nm hp, 22.7mJ/cm2



28nm hp, 46.3mJ/cm2



28nm hp, 71.6mJ/cm2

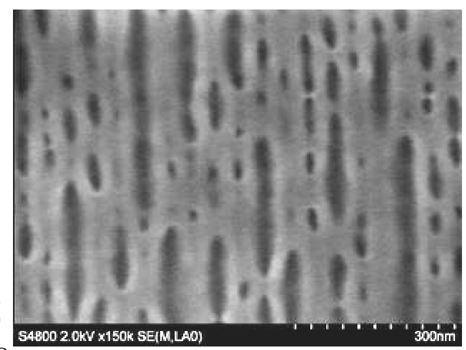


28nm hp, 79.1mJ/cm2

Materials and data courtesy of Roger Nassar, RHEM

ROHM AND HAAS ELECTRONIC MATERIALS
MICROELECTRONIC TECHNOLOGIES

LBNL-MET
Y-Monopole

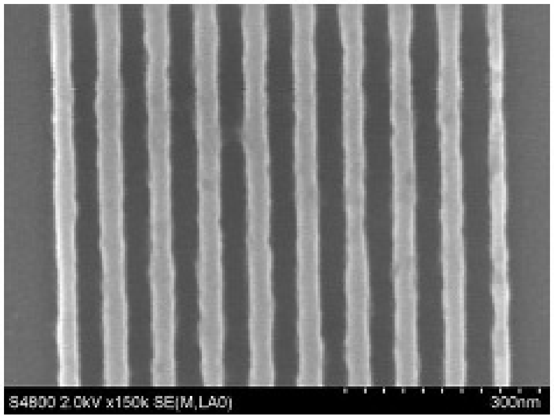


24nm hp, 79.1mJ/cm2

Ultrathin film effects limit the effectiveness of thickness reduction for improved resolution

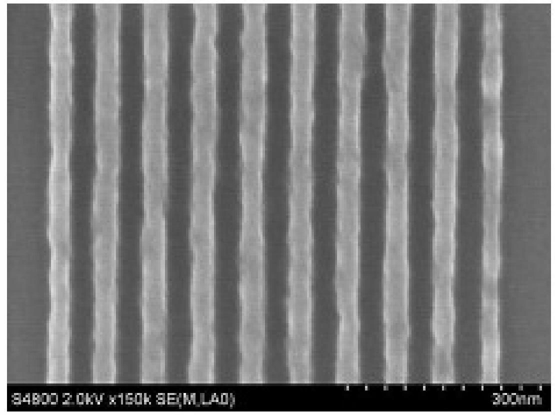
BERKELEY LAB

FT = 80nm



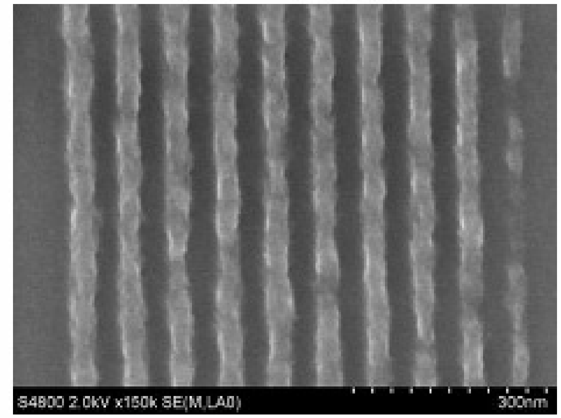
40L80P, 11.3mJ/cm²
LER=3.7±0.7

FT = 62nm



40L80P, 10.8mJ/cm²
LER=4.2±0.9

FT = 40nm



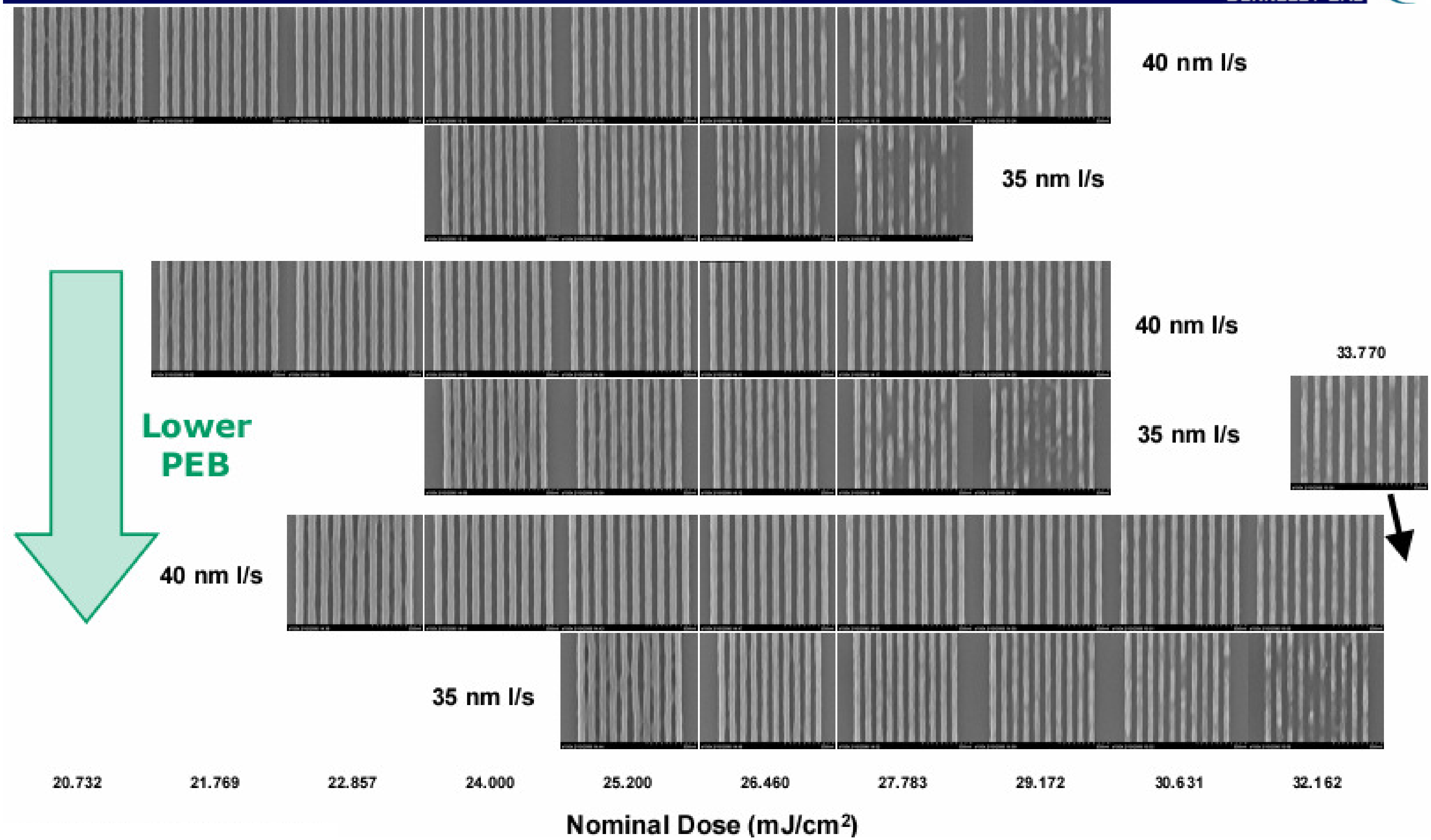
40L80P, 10.8mJ/cm²
LER=7.1±1.1

- Top-loss and LER become worse with decreasing thickness
- Film dominated by interface effects
- Is it possible to mitigate these effects with BARC and/or topcoat?

Data courtesy of
Tom Wallow, AMD

XP6305-G resist,
LBNL-MET, Y-Monopole

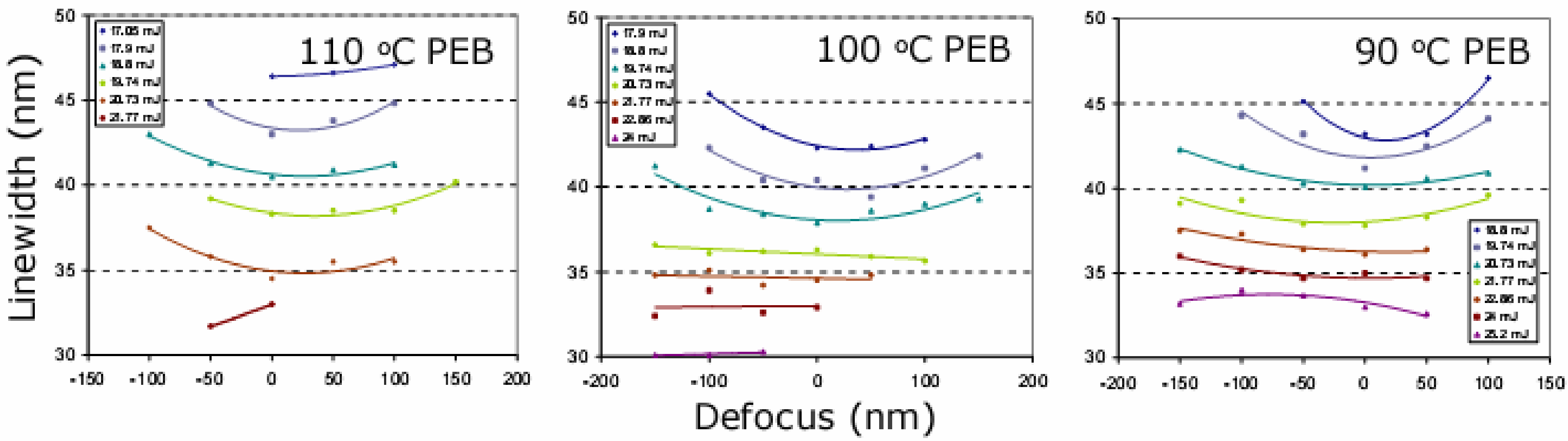
PEB reduction improves exposure latitude, but at the cost of reduced sensitivity

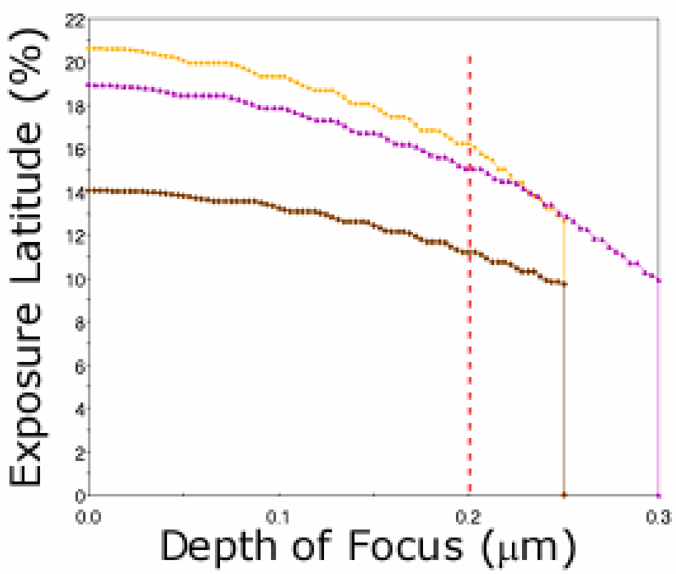


XP6305-A resist, LBNL-MET, Y-Monopole

Data courtesy of Tom Wallow, AMD

PEB reduction gains quickly saturate

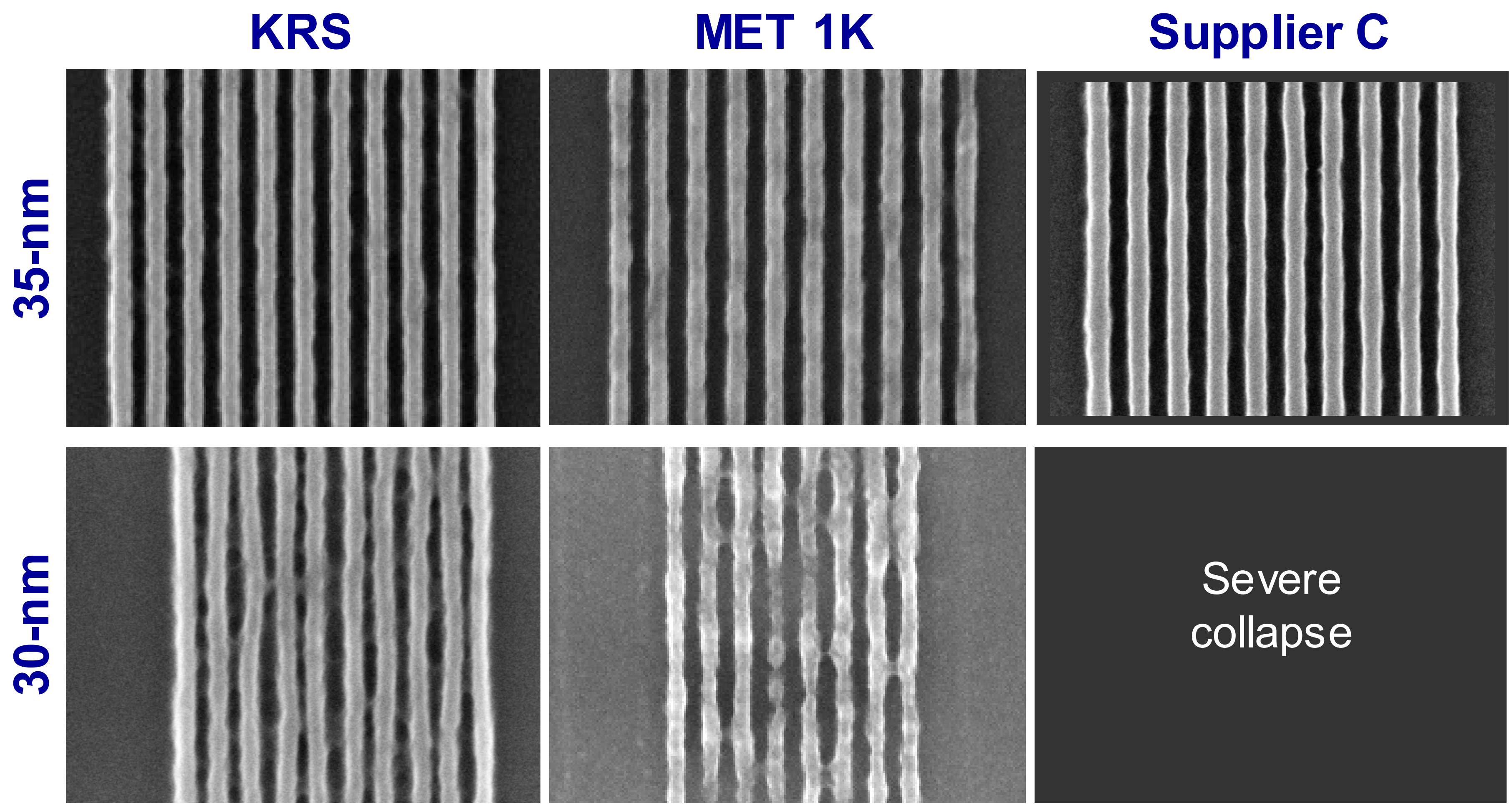




PEB Temperature (°C)	EL (%) (at 200nm DOF) (+/- 10% CD)
90	16.2
100	15.1
110	11.2

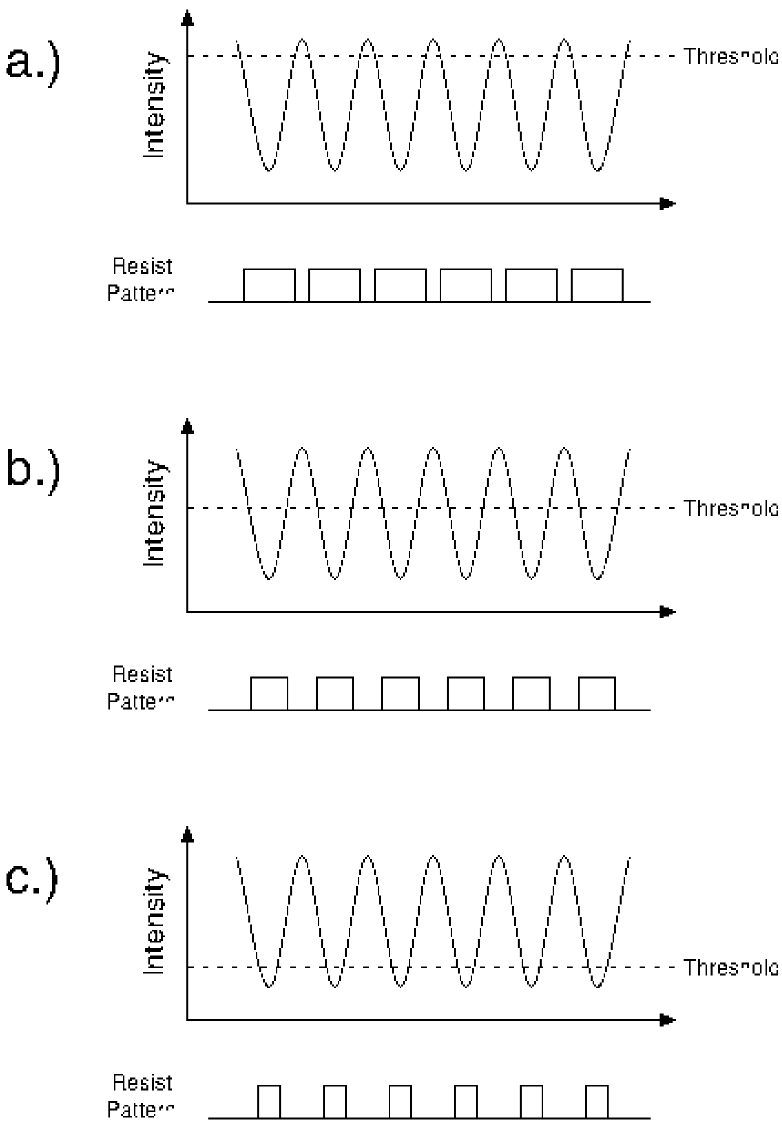
Data courtesy of
Tom Wallow, AMD

What is the best metric for characterizing intrinsic resolution?



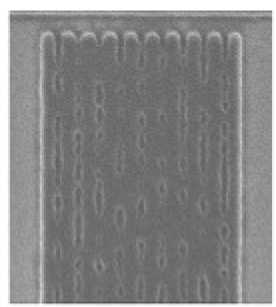
LBNL-MET, Y-Monopole

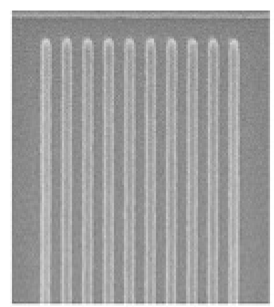
Resist based MTF measurements provide insight into resist and system properties

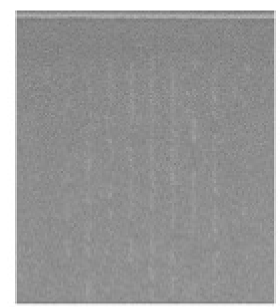


- MTF = pitch-dependent contrast
- Contrast determined from:
  - D_{max}, the dose at which resist lines first begin to clear
  - D_{min}, the dose at which resist lines disappear

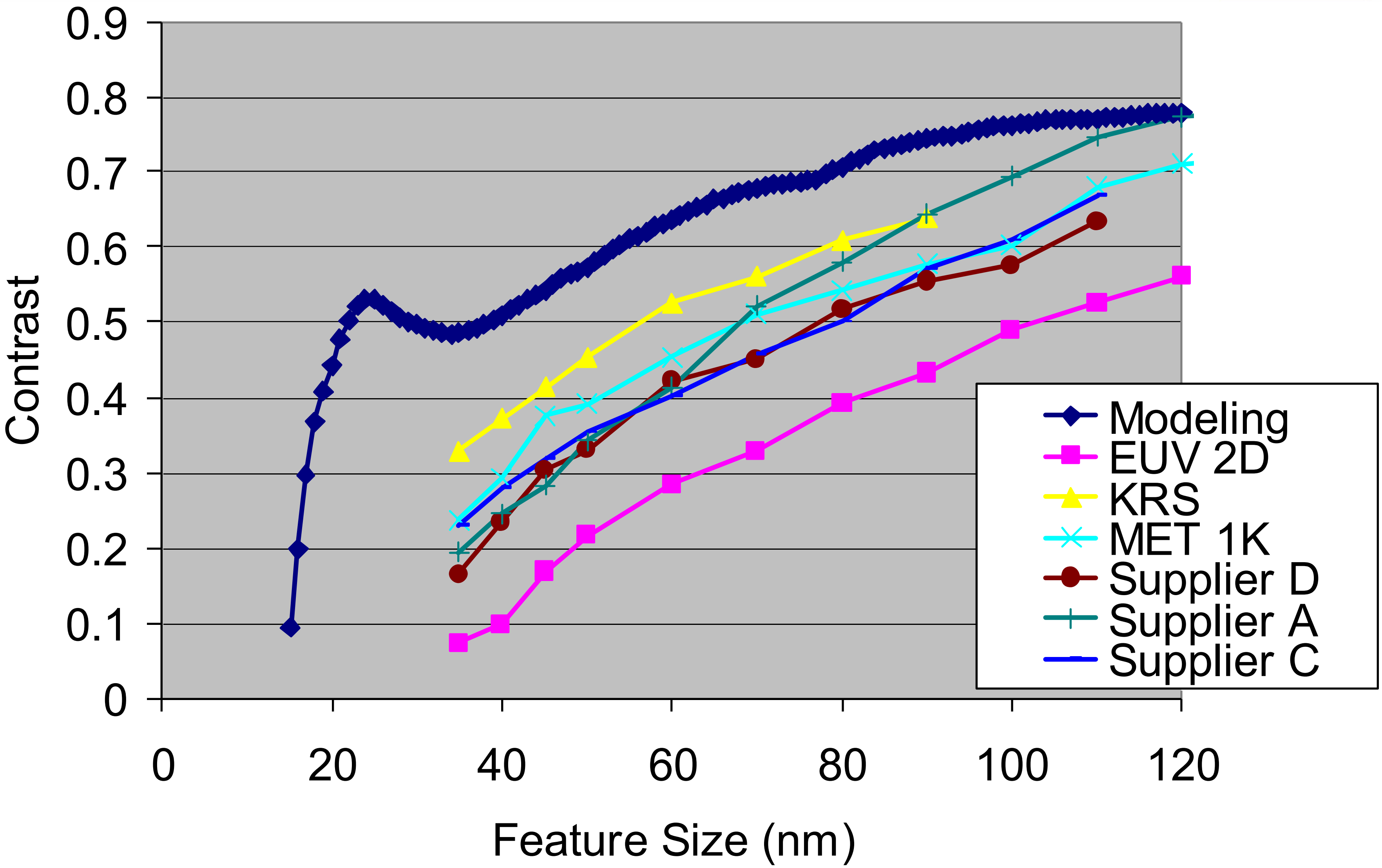
$$Contrast = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{D_{max} - D_{min}}{D_{max} + D_{min}}$$







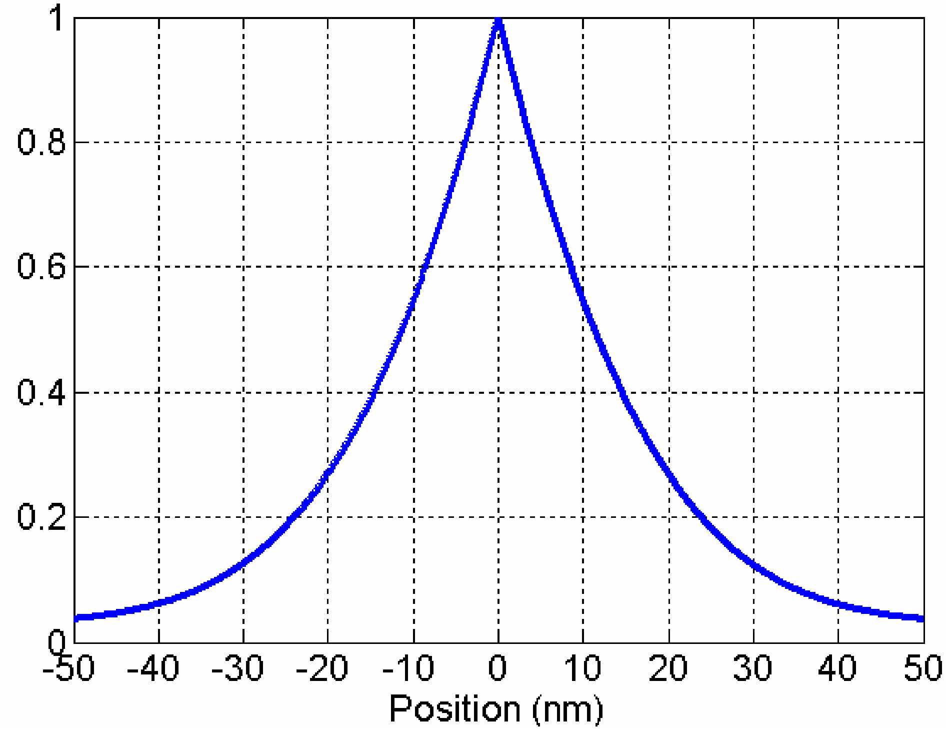
Resist performance has strong impact on measured contrast



Modeling Resist Using Simple Point-Spread-Function (PSF) Method

- PSF resist modeling* is fast and convenient
- Model easily generated
- Provides intuitive link to resist resolution limit
- Few parameters makes model less susceptible to extrapolation errors
- Resist process well approximated by deprotection function**

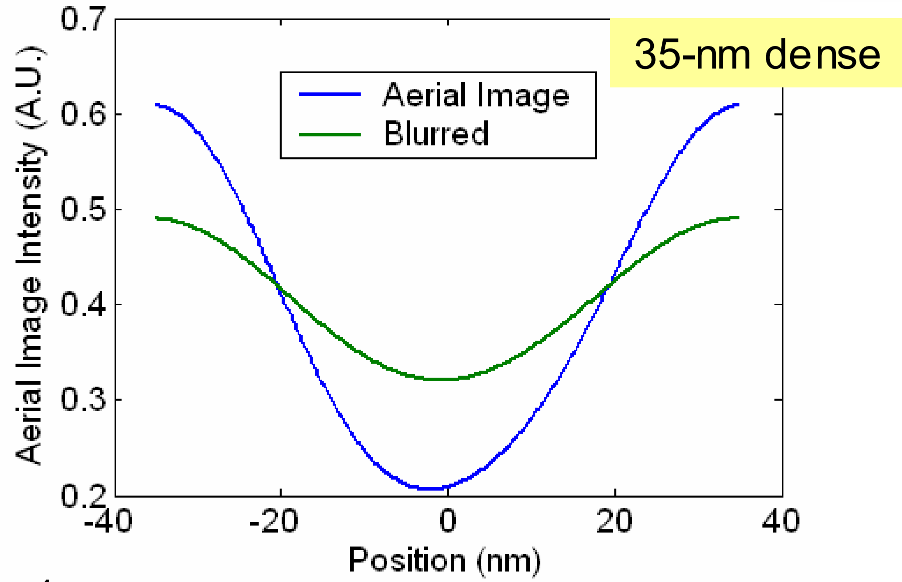
“Deprotection blur” function PSF

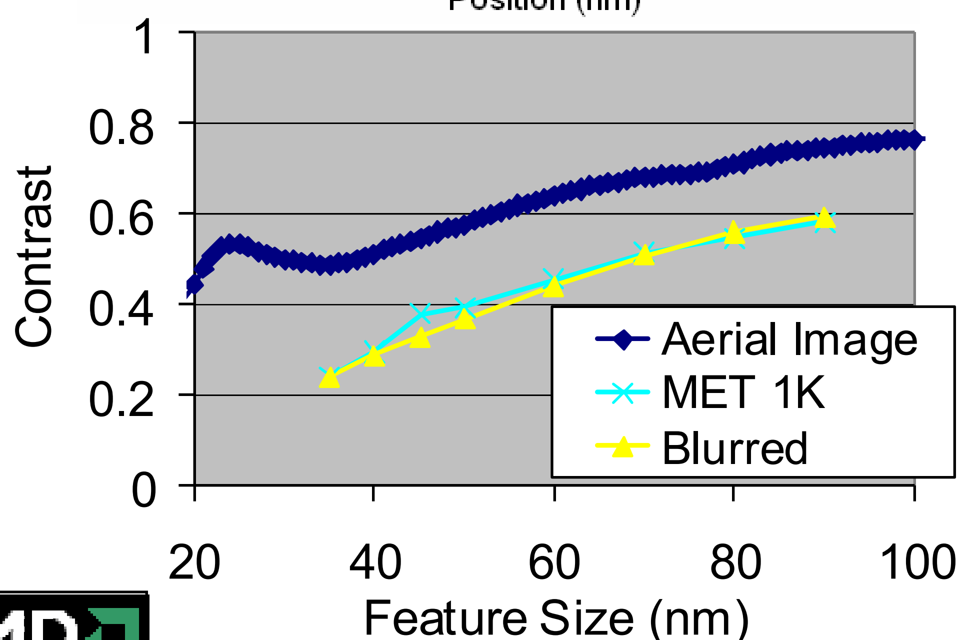


* C. Ahn, H. Kim, K. Baik, “A novel approximate model for resist process,” Proc. SPIE **3334**, (1998).

** Gregg Gallatin, “Resist Blur and Line Edge Roughness,” Proc. SPIE 5754, (2005)

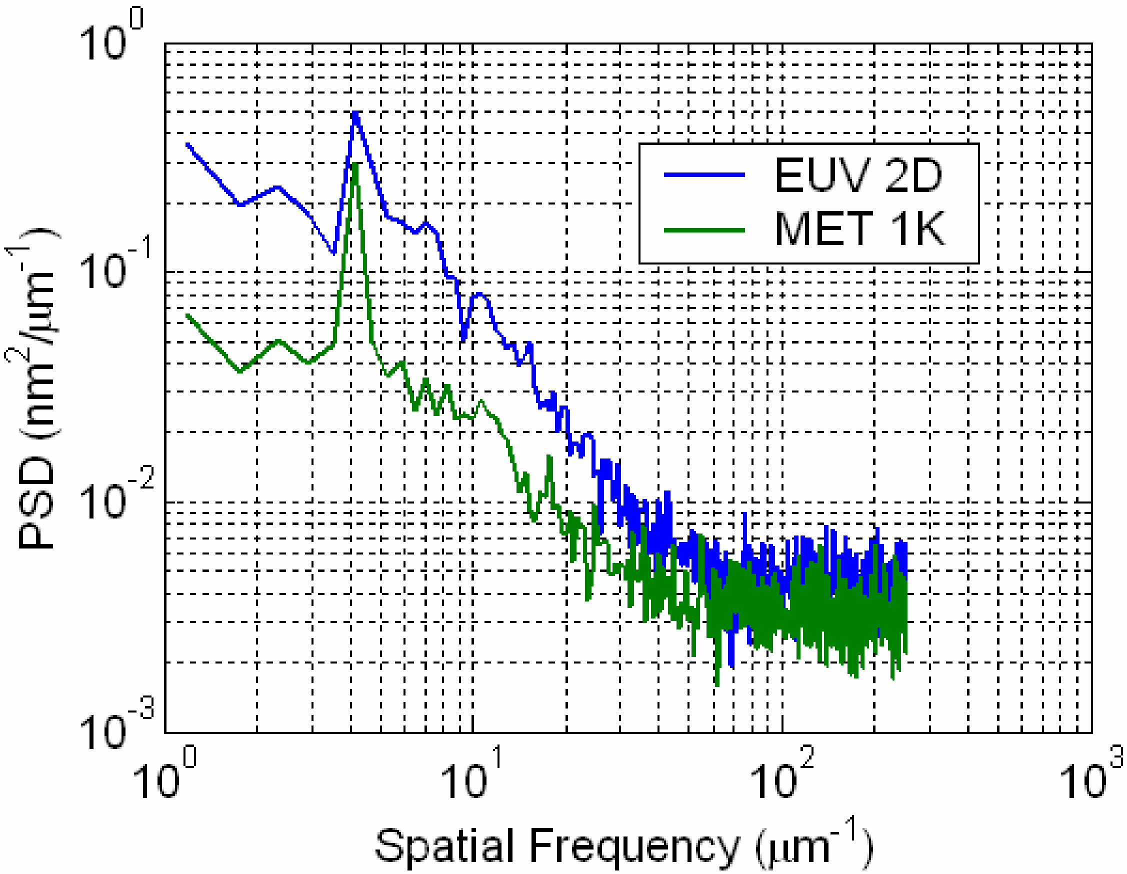
Extracting the deprotection blur from MTF data





Resist	Res. (nm)	Blur (nm)
EUV 2D	50	45
Supplier A	35	24
KRS	32.5	14
MET 1K	35	21
Supplier C	35	22

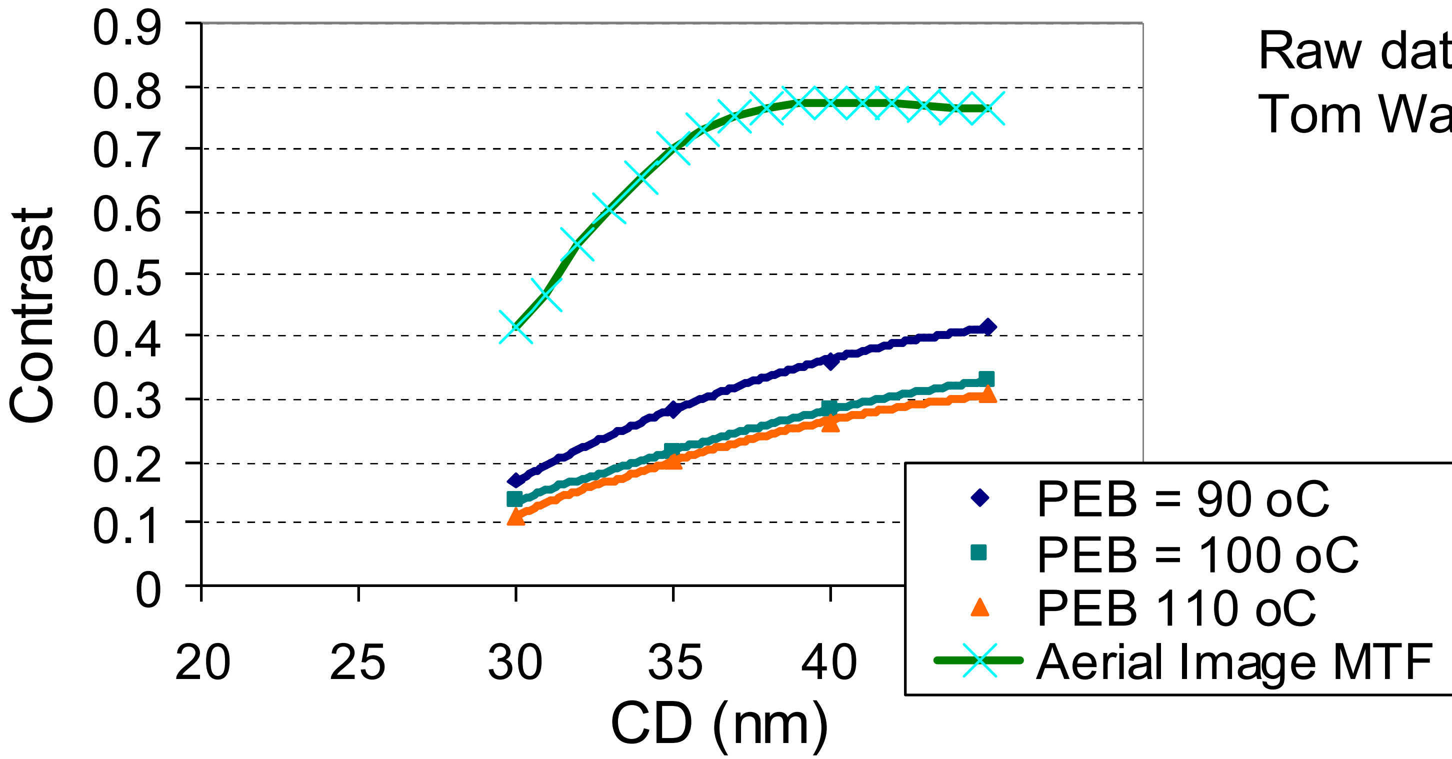
LER roll-off as a resolution metric



Resist	Res. (nm)	L_c (nm)
EUV 2D	50	24
Supplier A	35	20
KRS	32.5	18
MET 1K	35	22
Supplier C	35	28
Supplier E	35	26
Supplier F	30	25

LER roll-off (correlation length) is NOT a good indicator of resolution

Comparing MTF and Correlation Length Metrics for Process Studies



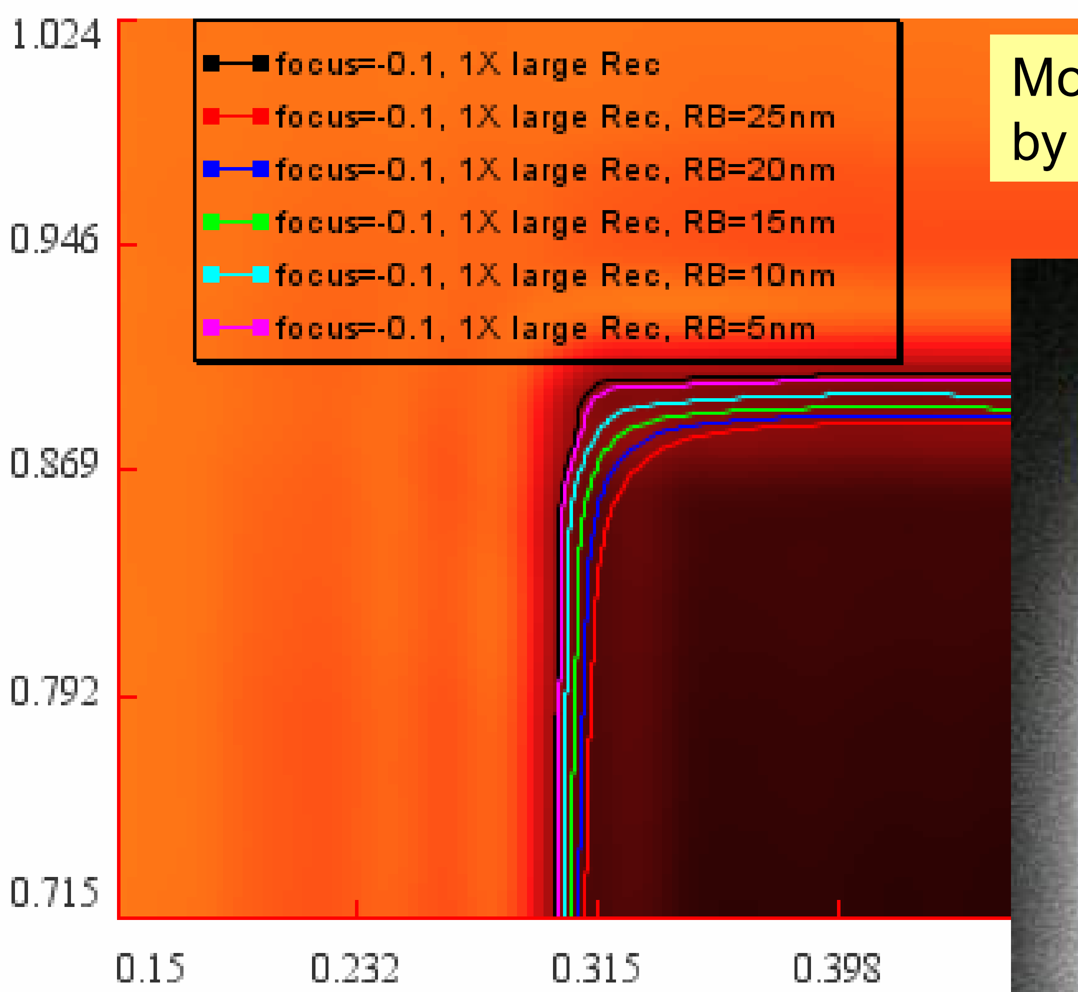
Raw data courtesy of Tom Wallow, AMD

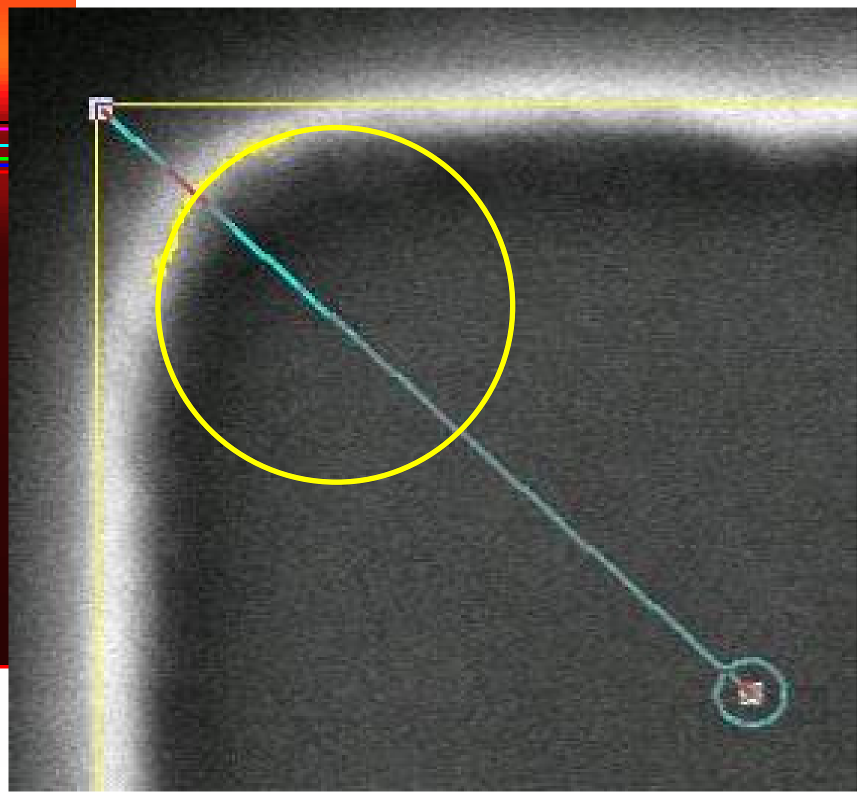
PEB	Blur (nm)	L_c (nm)
90° C	22	20.7
100° C	29	23.8
110° C	32	22.6

Corner Rounding as a Resolution Metric

- Use fine-corner detail in large feature to determine resolution limit

Modeling data provided by Ryoung-han Kim, AMD





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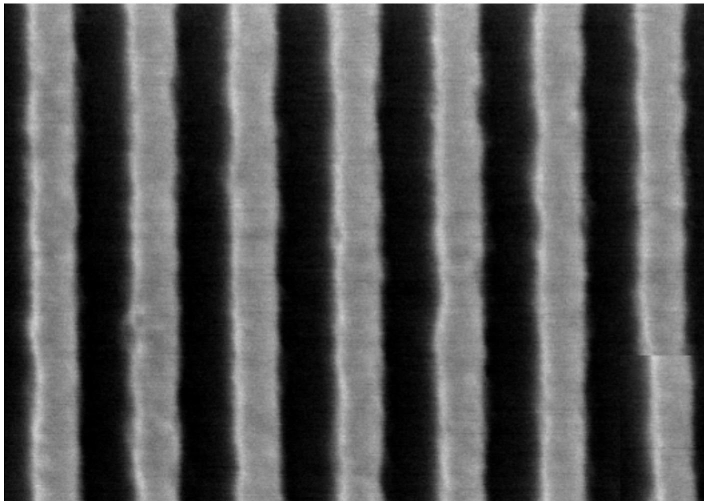
Performance of the Corner Rounding Metric

Resist	Res.(nm)	Corner Radius (nm)	Blur* (nm)
EUV 2D	50	87	
MET 1K	35	56	
Supplier E	35	60	
Supplier F	30	45	

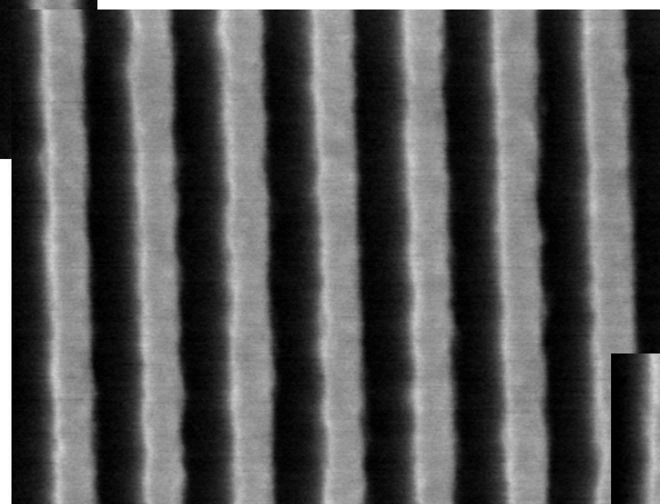
Corner-rounding appears to be good predictor of resolution

Corner-Rounding Analysis Showed Supplier F to be Best Sample: Printing Results



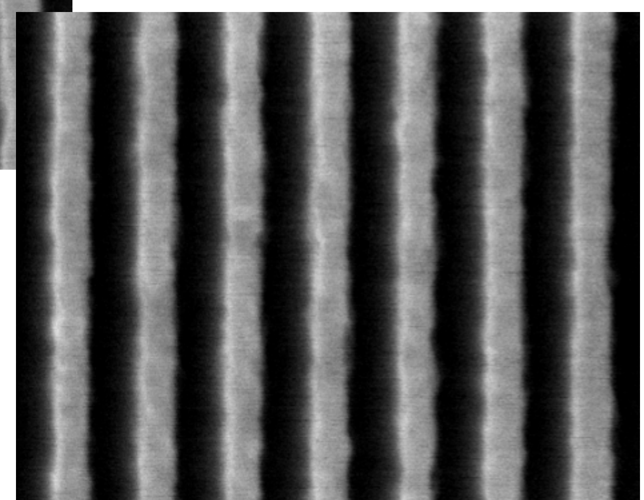
Coded 45-nm:90-nm
Actual 38-nm:90-nm
LER 3.0 nm: L = 403 nm

Dose to size
(50-nm 1:1)
= 19 mJ/cm^2



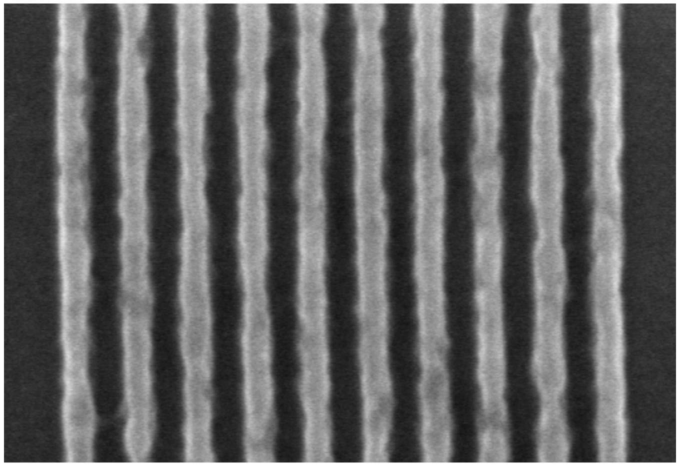
Coded 40-nm:80-nm
Actual 33-nm:80-nm
LER 3.1 nm: L = 403 nm

LBNL-MET
Y-Monopole

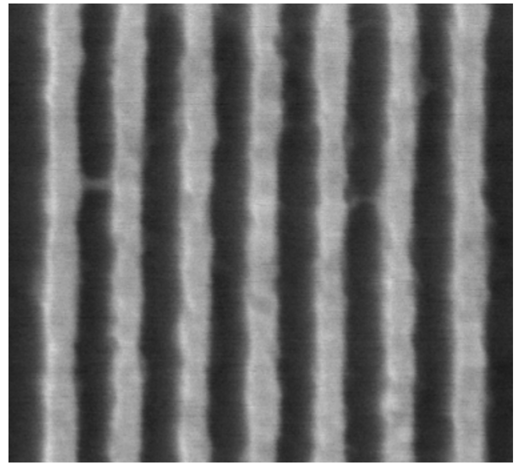


Coded 35-nm:70-nm
Actual 27-nm:70-nm
LER 3.0 nm: L = 366 nm

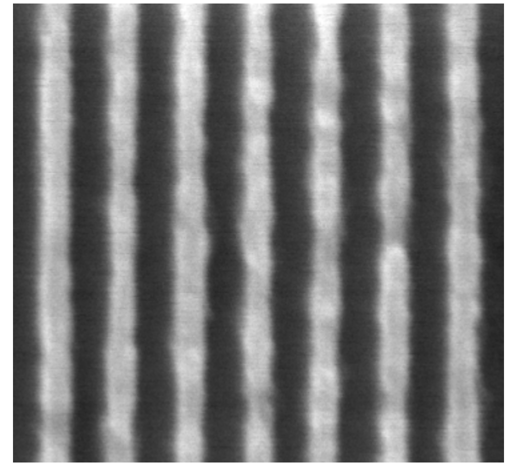
More Supplier F Printing Results



Coded 32.5-nm:65-nm
Actual 28-nm:70-nm
LER 4.4 nm: L = 407 nm

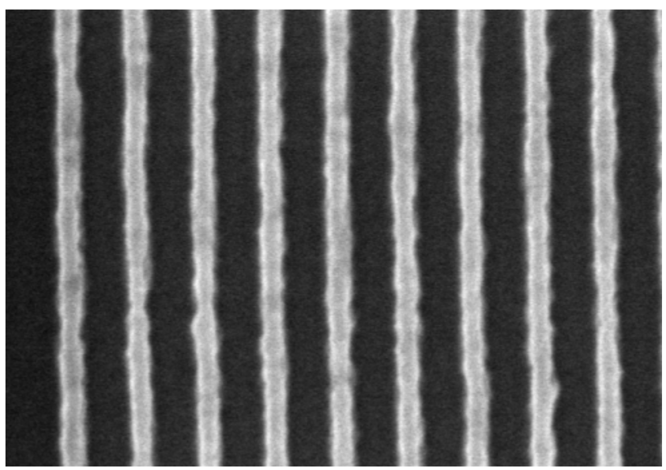


Coded 30-nm:60-nm
Actual 24-nm:60-nm
LER 4.0 nm: L = 350 nm



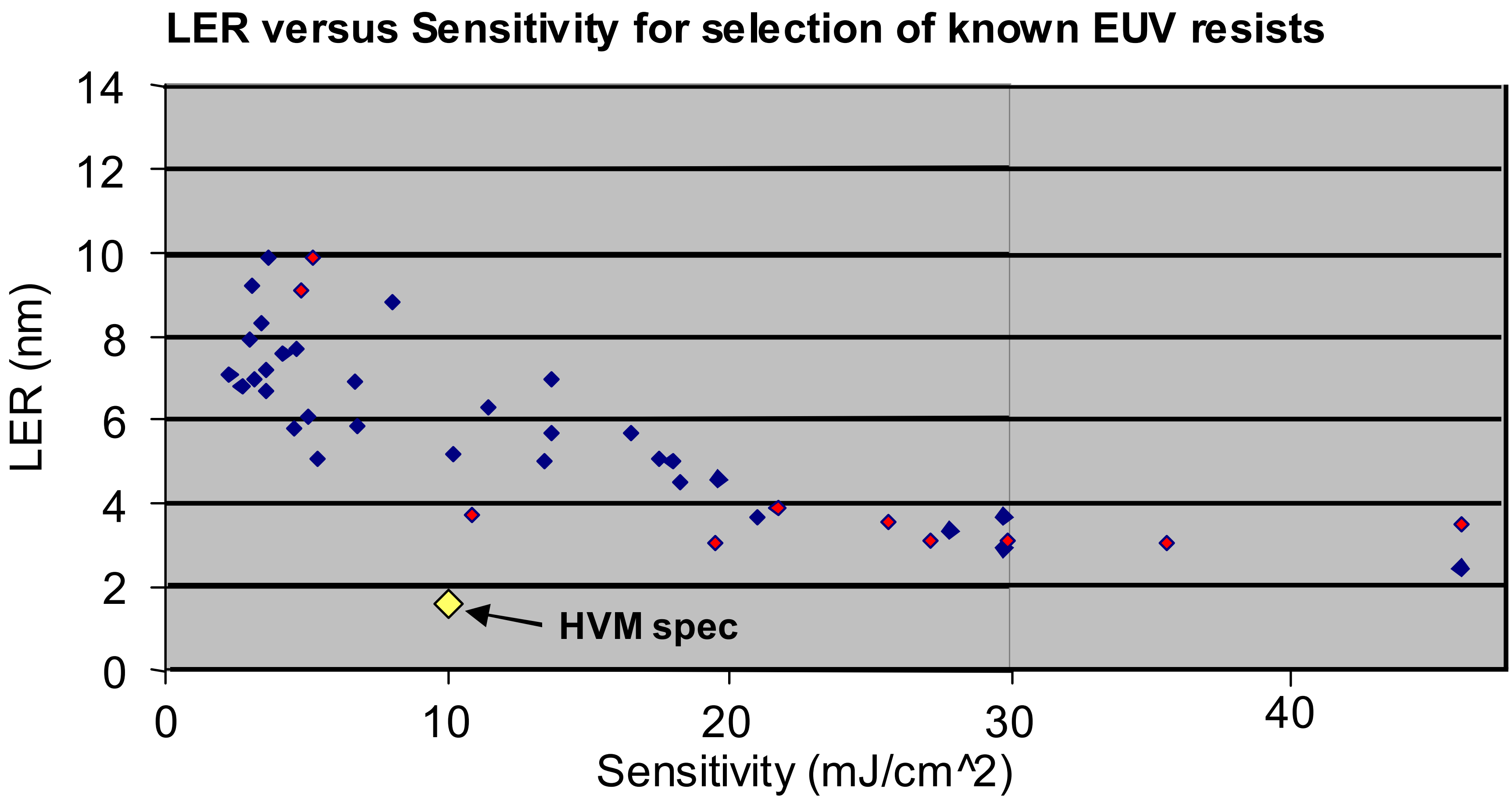
Coded 30-nm:60-nm
Actual 21-nm:60-nm
LER 4.0 nm: L = 350 nm

LBNL-MET
Y-Monopole



Coded 22.5-nm:67.5-nm
Actual 22.7-nm:67.5-nm
LER 4.0 nm: L = 512 nm

EUV Resist LER & Sensitivity



Status: Line Edge Roughness (HVM Spec): < 1.6 nm
Line Edge Roughness (Best Current): 2.5 nm

Summary

- The SEMATECH MET facility at Lawrence Berkeley National Lab provides ultrahigh resolution capabilities from a conventional projection EUV system
- EUV resolution is currently resist limited
- High sensitivity requirements places stringent constraints on resist resolution improvements
- Interface effects may require the use of more complex film stacks
- MTF and corner-rounding provide good metrics for intrinsic resolution
- A new resist outperforming KRS has been identified
    - 30-nm dense, 22.5-nm semi-isolated

Acknowledgments

Paul Denham
Brian Hoef
Gideon Jones
Jerrin Chiu
LBNL

Chris Anderson
UC Berkeley

Jim Thackeray
Roger Nassar
Rohm and Haas

Carl Larson
Greg Wallraff
IBM

Ryoung-han Kim
Bruno La Fontaine
Tom Wallow
AMD

Kim Dean
SEMATECH

Supported by: